On the Weak Decay of Composite System based on Majorana Partners

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In a composite model of leptons and quarks, composite particles with heavy Majorana particles appear provided that the V-rishon is regarded as a Majorana particle. In this paper, the decay mode of such "Majorana partners" is investigated. It is shown that the life time of Majorana partners are fairly long. Our model suggests that a new mechanism of proton decay is possible, where the X and Y bosons in GUTs are not necessary.

§1. Introduction

In the progress of high-energy physics, the so-called energy frontier approaches to TeV region, where discoveries of new phenomena and/or new particles such as the super-partners are expected. In such situation, we have proposed in a few years ago a model of leptons and quarks on the basis of possible Majorana-partner in rishon model.[1] Our model is, however, in the stage of formal proposal and characteristics concerning to the decay properties etc are not yet made clear. When a new particle is observed, the decay properties will play an important role in the decision of its nature. This paper is concerning to this problem.

It should be noted that the treatment of composite system is generally complicated compared with the simple system based on field theory such as SUSY. However, the weak interaction of composite system had been formulated in an appropriate way containing semi-empirical approach in the development of particle physics in the stages when little is known concerning to the nature of constructive force of composite system. In this paper, we will in first summarize the essence of our model. In section 3, quick review the treatments of weak interaction of composite system is given. Then, weak decay properties of our composite system are investigated. The discussion is given in the final section.

§2. Composite model of leptons and quarks based on Majorana partner

The essence of our model is summarized as follows. In the rishon model,the leptons and quarks are given as[2]

$$u = TTV, \;\; d = \tilde{V}\tilde{V}\tilde{T}, \;\; \nu_e = VVV, \;\; e^- = \tilde{T}\tilde{T}\tilde{T} \tag{2·1}$$

where the V rishon is purely electrically neutral, then it is possible to introduce the Majorana property on V. It should be noted that we have used symbolically the notation $\tilde{V}$ as the anti-particle of V. Though the particle and anti-particle are identical in the Majorana neutrino theory, they are distinguished historically and

phenomenologically through the difference of their interactions by that of helicity. In fact in the Majorana neutrino theory, the difference between "neutrino" and "antineutrino" is reduced to the difference of helicity state.[3] In this paper, we use the symbol $\tilde{V}$ in this meaning.

For the V rishon, let us consider the Dirac-Majorana (D-M) mass term[3]−[5] in the simplest case of one generation. We have[*]

$$\mathcal{L}^{\text{D-M}} = -\frac{1}{2}m_L\overline{(V_L)^c}V_L - m_D\bar{V}_RV_L - \frac{1}{2}m_R\bar{V}_R(V_R)^c \quad + \quad \text{h.c.} \tag{2·2}$$

From Eqs. (2·2) we have

$$\mathcal{L}^{\text{D−M}} = -\frac{1}{2}\sum_{\alpha=1}^{2}m_\alpha\bar{\chi}_\alpha\chi_\alpha \tag{2·3}$$

where

$$\begin{aligned}V_L &= \cos\theta\chi_{1L} + \sin\theta\chi_{2L}\\(V_R)^c &= -\sin\theta\chi_{1L} + \cos\theta\chi_{2L}.\end{aligned} \tag{2·4}$$

Here χ_1 and χ_2 are fields of Majorana V rishon with masses m_s (a "small" mass), m_B (a "Big" mass), respectively. Assuming now that

$$m_L = 0, \quad m_D \simeq m_F, \quad m_R \gg m_F \tag{2·5}$$

and

$$m_s \simeq \frac{m_D^2}{m_R}, \quad m_B \simeq m_R \quad \theta \simeq \frac{m_D}{m_R} \tag{2·6}$$

where m_F is a typical mass of the rishon, particles with definite masses are distinguished as a very light Majorana V rishon with mass $m_s \ll m_F$ and a very heavy Majorana particle with mass $m_B \simeq m_R$. The current V rishon field, V_L, nearly coincides with χ_{1L}, and $\chi_2 \simeq V_R + (V_R)^c$, because θ is extremely small. It should be noted that V_L and $(V_R)^c$ represent the states corresponding to that concerning the possible weak interaction, while χ_1 and χ_2 are the mass eigenstates. Hereafter, we use the notation

$$V_s \equiv \chi_1 \quad (\text{mass } m_s) \qquad V_B \equiv \chi_2 \quad (\text{mass } m_B) \tag{2·7}$$

In our scheme, the V rishon V_s is a Majorana particle with mass much smaller than those of the other fermions. The predictions for the V rishon mass depend on the value of the m_R mass.

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[*] In a classification scheme based on the hyper-color and color group $SU_3(H) \times SU_3(C)$, the singlet property of the Majorana mass term may be destroyed if the rishon belongs to the fundamental representation. The **8** representation seems to avoid this difficulty. The details of the resolution of this problem will be discussed elsewhere.

In the Dirac-Majorana mass scheme, the rishons V_s and V_B appear. In our scheme, the V rishon V_s is a Majorana particle with mass much smaller than those of the other fermions. The predictions for the V rishon mass depend on the value of the m_R mass.

The existence of V_B in Eq. (2·7) implies the new generation structure with additional particles shown in Table I, where TTV_s, $\tilde{T}\tilde{V}_s\tilde{V}_s$, $V_sV_sV_s$ and $\tilde{T}\tilde{T}\tilde{T}$ represent the observed quarks and leptons, u, d, ν and e^-, respectively. In addition, new heavy quarks TTV_B, $\tilde{T}\tilde{V}_s\tilde{V}_B$ and $\tilde{T}\tilde{V}_B\tilde{V}_B$ and heavy neutrinos $V_sV_sV_B$, $V_sV_BV_B$ and $V_BV_BV_B$ appear. They are characterized by their configurations containing the heavy V rishon V_B. The row corresponding to ν lists the mass eigenstates of neutrinos belonging to the first generation, and ν_e the state concerning the weak interaction, which is realized as a superposition of mass eigenstates.

Table I. Configuration of leptons and quarks constituting a generation, where the row corresponding to ν lists its mass eigenstates belonging to the first generation.

flavor	standard	B	BB	BBB
u	TTV_s	TTV_B		
d	$\tilde{T}\tilde{V}_s\tilde{V}_s$	$\tilde{T}\tilde{V}_s\tilde{V}_B$	$\tilde{T}\tilde{V}_B\tilde{V}_B$	
ν	$V_sV_sV_s$	$V_sV_sV_B$	$V_sV_BV_B$	$V_BV_BV_B$
e^-	$\tilde{T}\tilde{T}\tilde{T}$			

It should be emphasized that the new scheme satisfies the anomaly-free condition at the level of leptons and quarks; [*)] that is, the condition $\sum Q = 0$ is satisfied.

It should be noted that in the seesaw mechanism, if the mass of V_B is of the order of the Planck mass, the generation structure will not be affected in practice. The most interesting case is in which the mass of V_B is not extremely large, for example, on the order of possible super-partners. In such a case, heavy quarks and neutrinos appear at the level of leptons and quarks. In the special case in which the two Majorana particles have exactly the same mass, $m_{V_s} = -m_{V_B}$, they will behave as if a single Dirac particle did, which is often called a "pseudo Dirac particle".

§3. Electroweak interaction in composite system

What form does our compositeness appear in electroweak interaction? We will examine the case when the compositeness of leptons and quarks are extremely suppressed and leptons and quarks themselves behave as if elementary particles in the realization of electroweak structure.

3.1. *Electroweak interaction in quarks and nucleons*

In order to investigate the electroweak interaction of composite system, we will firstly compare the case of quark doublet $\binom{u}{d}$ with that of hadron doublet $\binom{p}{n}$, where $p = (uud)$ and $n = (udd)$.

[*)] In this paper, we have assumed that the gauge structure appears at the level of leptons and quarks, as a result of the dynamics of the sub-system, and the anomaly-free condition is formally realized at this level. In this sense, the meaning of this condition in the sub-system seems to be rather ambiguous.

Under $SU(2)_L \times U(1)$, the weak doublet of quarks u and d is given as

$$q_L = \begin{pmatrix} u \\ d \end{pmatrix}_L \tag{3.1}$$

where the electric charge is $Q = I_3 + Y$, and $Y = 1/6$. After the standard procedure, the weak charged current is given as

$$J_\mu = \bar{q}\gamma_\mu(1 + \gamma_5)\frac{1}{2}(\tau_1 + i\tau_2)\, q\ + h.c. \tag{3.2}$$

Explicit representation of Eq. (3.2) is

$$J_\mu = \bar{u}\gamma_\mu(1 + \gamma_5)\, d\ + h.c. \tag{3.3}$$

In the charged weak current of hadrons, it should be noted that proton and neutron are composite system of quarks, $p = (uud)$ and $n = (udd)$. The elementary process is caused by quarks, then the basic structure of weak current of hadrons is the same as that of quarks. However, the weak current of hadrons are affected by the compositeness.

$$J_\mu = \bar{p}\gamma_\mu(C_V + \gamma_5 C_A)d,\ \ + h.c. \tag{3.4}$$

Because of the conservation of vector current, C_V is not renormalized, while the axial vector current is only partially conserved, [*)] then C_A is renormalized.

It should be noted that the same electroweak structure of proton and neutron is obtained provided that the weak doublet

$$N_L = \begin{pmatrix} p \\ n \end{pmatrix}_L \tag{3.5}$$

is taken, where the electric charge is $Q = I_3 + Y$, and $Y = 1/2$. In this case, the weak charged current is given as

$$J_\mu = \bar{p}\gamma_\mu(1 + \gamma_5)n,\ \ + h.c. \tag{3.6}$$

[*)] The CVC and PCAC can be easily shown by making use of model Lagrangian. The Lagrangian of u and d quarks is given as

$$\mathcal{L} = -\bar{q}(-i\gamma^\alpha \partial_\alpha + m_q)q + \mathcal{L}_I$$

where $\mathcal{L}_I$ is the interaction term where derivative is generally not contained. For the infinitesimal transformation

$$q \longrightarrow (1 + \frac{i}{2}\tau_k u_k)q$$

$$J_k^\alpha = \bar{q}\gamma^\alpha \frac{1}{2}\tau_k q,$$

$$\partial_\alpha J_k^\alpha = 0.$$

For the axial-vector current, the PCAC relation is obtained,

$$q \longrightarrow (1 + \frac{i}{2}\gamma^5 \tau_k u_k)q$$

$$J_k^{5\alpha} = \bar{q}\gamma^\alpha \gamma^5 \frac{1}{2}\tau_k q,$$

$$\partial_\alpha J_k^{5\alpha} = im_q \bar{q}\gamma^5 \tau_k q.$$

Eq. (3·6) is same as Eq. (3·4) except the factors C_V and C_A.

That is, the effective electroweak structure with the same structure appears in the level of protons and neutrons.[6)]

3.2. *Effective electroweak interaction in composite system*

Thus, we will consider the case in which the processes concerning the sub-structure are extremely suppressed and composite leptons and quarks themselves behave as if elementary particles in the realization of electroweak structure. In the original rishon model, the leptons and quarks in this model are given as[2)]

$$u = TTV, \quad d = \tilde{V}\tilde{V}\tilde{T}, \quad \nu = VVV, \quad e^- = \tilde{T}\tilde{T}\tilde{T} \tag{3·7}$$

where ν represents the neutrino belonging to mass eigenstate, and the state contributing to weak interaction ν_e is a superposition of such states. It should be noted that the V rishon is purely electrically neutral, therefore it is possible to introduce the Majorana interaction on V.

Though a few models are proposed to introduce the generation structure, in this paper, we will represent the generation structure byintroducing the generation suffix i for each rishon doublets. Then, the leptons and quarks in our system are given as,

$$U_i = T_iT_iV_i, \quad D_i = \tilde{V}_i\tilde{V}_i\tilde{T}_i, \quad \nu_i = V_iV_iV_i, \quad l_i = \tilde{T}_i\tilde{T}_i\tilde{T}_i. \tag{3·8}$$

In the case when the realization of electroweak structure is extremely suppressed by some reason, the relevant electroweak structure will appear only for composite system in Eq. (3·8). The Lagrangian density in our such system is given as

$$\mathcal{L} = \mathcal{L}_I - \sum_{i=1}^{3} \bar{L}_i\gamma_\mu(\partial_\mu - ig\mathbf{t}\cdot\mathbf{A}_\mu - ig'YB_\mu)L_i - \sum_{i=1}^{3}\sum_{\kappa=U,D} \bar{R}_i^\kappa(\partial_\mu - ig'YB_\mu)R_i^\kappa$$

$$- \sum_{i,j=1}^{3} (\bar{L}_i\phi R_j^D M_{ij}^D + h.c.) - \sum_{i,j=1}^{3} (\bar{L}_i(-\eta)\phi^* R_j^U M_{ij}^U + h.c.)$$

$$+ \mathcal{L}'(lepton\ term) \tag{3·9}$$

where

$$L_i = \frac{1+\gamma_5}{2}\begin{pmatrix} U_i \\ D_i \end{pmatrix}, \quad R_i^U = \frac{1-\gamma_5}{2}U_i, \quad R_i^D = \frac{1-\gamma_5}{2}D_i \tag{3·10}$$

and

$$\eta = \begin{pmatrix} 0 & I \\ -I & 0 \end{pmatrix}.$$

The scalar field ϕ, the gauge field $\mathbf{A}_\mu$ and B_μ transform as a doublet, triplet and singlet, respectively under weak rotation $SU(2)_L$.

The effect of symmetry breaking is obtained by replacing

$$\phi^0 \to e^{i\theta}(v + \phi^{0\prime}) \tag{3·11}$$

where v represent of the magnitude of vacuum expectation value of ϕ^0 field,

$$\langle 0|\phi^0| = e^{i\theta}v \tag{3.12}$$

Now, we must consider the diagonalization of the mass term $\mathcal{L}_{mass}$ obtained from Eqs. (3·9) - (3·12),

$$\mathcal{L}_{mass} = -\sum_{i,j=1}^{3} \bar{D}_{Li}(e^{i\theta}vM_{ij}^{D})D_{Rj} + h.c.)$$
$$-\sum_{i,j=1}^{3} \bar{U}_{Li}(e^{-i\theta}vM_{ij}^{U})U_{Rj} + h.c.) \tag{3.13}$$

Performing an appropriate unitary transformation,

$$\mathcal{L}_{mass} = \bar{D}_L M_D D_R + \bar{U}_L M_U U_R + h.c. \tag{3.14}$$

the mass term Eq. (3·14) can be diagonalized. The result is given as,

$$U_i = \sum_l V_{il}^{(U)}U_l \ , \ D_i = \sum_k V_{ik}^{(D)}D_k \tag{3.15}$$

The mass matrices in Eq. (3·15) are given as,

$$M_D = (V^{(D)\dagger}(e^{i\theta}vM_{ij}^{D})V^{(D)}) \ \ M_U = (V^{(U)\dagger}(e^{-i\theta}vM_{ij}^{U})V^{(U)}) \tag{3.16}$$

where the prime mark of diagonalized fields is abbreviated for simplicity of description. It should be noted that the CKM matrix is given as,

$$K = V^{(U)}V^{(D)\dagger} \tag{3.17}$$

It should be noted that our formulation of this section is parallel with the standard procedure. That is, though the fundamental system is composite, the composite systems behave partially as if they are elementary particles. In what form, does rare process appear on the basis of the sub-structure ?

§4. Pre-electroweak structure for sub-constituents

In this section, we will treat the simplest case with one generation for simplicity. Then, the weak-doublets in our system is given as,

Table II. Leptons and quarks belonging to the first generation.

Q	flavor	$B1$	$B2$	$B3$
2/3	u	u_{B_1}		
−1/3	d	d_{B_1}	d_{B_2}	
0	ν	ν_{B_1}	ν_{B_2}	ν_{B_3}
−1	e^-			

$$\Psi_L = \begin{pmatrix} T \\ \tilde{V} \end{pmatrix}_L. \tag{4.1}$$

In order to see the essential nature, we will in this section restrict to one generation case, because general mixing scheme in this case is complicated.

The electroweak Lagrangian in our system is given as

$$\mathcal{L} = -\ \bar{\Psi}_L \gamma_\mu (\partial_\mu - ig\mathbf{t} \cdot \mathbf{A}_\mu^{(\mathbf{s})} - ig'YB_\mu^{(s)})\Psi_L - \sum_{\kappa=T,V} \bar{\Psi}_R^\kappa (\partial_\mu - ig'YB_\mu^{(s)})\Psi_R^\kappa$$

$$-\ (\bar{\Psi}_L \phi \bar{\Psi}_R^V M^{(V)} + h.c.) - (\bar{\Psi}_L(-\eta)\phi^* \bar{\Psi}_R^T M^{(T)} + h.c.) \tag{4.2}$$

where $\mathbf{A}_\mu^{(s)}$ and $B_\mu^{(s)}$ are the gauge fields concerning to sub-system. The electric charge of component of doublet Eq. (4.1) is given as

$$Q = I_3 + Y \tag{4.3}$$

in the unit of e/3, and $Y = -1/2$. After symmetry breaking, the sub-gauge bosons $W_\mu^{(S)\pm}$, $Z_\mu^{(S)}$ and $A_\mu^{(s)}$ bosons appear, where they are characterized by the charge unit e/3. The ordinary electroweak gauge bosons W_μ, Z_μ and A_μ will be formally expressed by making use of the sub-gauge bosons $W_\mu^{(s)}$, $Z_\mu^{(s)}$ and $A_\mu^{(s)}$ as,

$$W_\mu = (W^{(s)}W^{(s)}W^{(s)})_\mu$$
$$Z_\mu = (Z^{(s)}Z^{(s)}Z^{(s)})_\mu$$
$$A_\mu = (A^{(s)}A^{(s)}A^{(s)})_\mu \tag{4.4}$$

It should be noted that Eq. (4.4) is a symbolical representation of composite system based on yet to be known mechanism. These sub-gauge bosons should be almost confined in the ordinary gauge bosons belonging the level of leptons and quarks. The effective electroweak structure in the level of leptons and quarks will be given by making use of Eq. (4.4).

In order to investigate the properties of composite system given by Eq. (4.4), let us examine the familiar β-decay process of d quark,

$$d + \nu_e \rightarrow u + e^- \tag{4.5}$$

In the picture of fundamental constituents, Eq. (4.5) is rewritten as,

$$(\tilde{V}\tilde{V}\tilde{T}) + (VVV) \rightarrow (TTV) + (\tilde{T}\tilde{T}\tilde{T}) \tag{4.6}$$

Thus, we see that the fundamental interaction in our process is

$$\mathcal{L} = g_w^{(s)} \bar{T} \gamma^\mu (1 + \gamma_5) \tilde{V} W_\mu^{(s)} \tag{4.7}$$

In our scheme, the elementary process such as

$$\tilde{V} + V \to T + \tilde{T} \tag{4.8}$$

is expected to be extremely suppressed as if quarks are almost completely confined, while the process such as Eq.(4·5) or equivalently Eq.(4·8) are enhanced similar to that the 3-body system of quarks are familiar ones.

Thus, on the basis of such normalization assumption, we will investigate possible decay mode of heavy particles with Majorana constituent V_B.

§5.   Weak decay of composite system with Majorana partners

It should be noted that the Majorana constituents in our model, V_s and V_B are the mass eigenstates, which are represented as superposition of the eigenstates of weak interaction, V_L and V_R^c,

$$\begin{aligned} V_{sL} &= \cos\theta V_L - \sin\theta V_R^c \\ V_{BL} &= \sin\theta V_L + \cos\theta V_R^c. \end{aligned} \tag{5.1}$$

It should be emphasized that V_R^c in Eq.(5·1) does not appear in ordinary weak interaction Lagrangian, and called as "sterile" particle.[7]

In order to investigate the β-decay process of our composite system, let us compare the decay processes of d and d_{B_1}.

The most familiar βdecay process of neutron is known to be caused by the $d \to u$ transition. By making use of Eq.(5·1), the fundamental transition behind $d \to u$ transition as composite system is symbolically represented as

$$\begin{aligned} &(T \to \tilde{V}, T \to \tilde{V}, V \to \tilde{T}) \\ &\quad = (\bar{\tilde{V}}_L \gamma_\mu (1 + \gamma_5) T\ cos\theta, \bar{\tilde{V}}_L \gamma_\mu (1 + \gamma_5) T\ cos\theta, \bar{\tilde{T}} \gamma_\mu (1 + \gamma_5) V\ cos\theta). \end{aligned} \tag{5.2}$$

It should be noted that Eq. (5·2) is physically equivalent with the leptons and quarks level interaction

$$\mathcal{L} = g \bar{u} \gamma^\mu (1 + \gamma_5) d\ W_\mu \tag{5.3}$$

then the strength of the interaction given by Eq. (5·2) should be "normalized" to that of Eq. (5·3) in a similar concept as renormalization.

The transition behind $d_{B_1} \to u$ transition of composite system with heavy constituent V_B is also represented as

$$\begin{aligned} &(T \to \tilde{V}, T \to \tilde{V}_B, V \to \tilde{T}) \\ &\quad = (\bar{\tilde{V}}_L \gamma_\mu (1 + \gamma_5) T\ cos\theta, \bar{\tilde{V}}_L \gamma_\mu (1 + \gamma_5) T\ sin\theta, \bar{\tilde{T}} \gamma_\mu (1 + \gamma_5) V\ cos\theta). \end{aligned} \tag{5.4}$$

In our case, the mass of V_B is expected to be very large. Then from Eq. (2·6), $cos\theta \sim 1$ and $sin\theta \sim \frac{m_D}{m_R}$. Thus, the strength of the process given by Eq. (5·4) is distinguished by the factor $sin\theta$ compared with the process given by Eq. (5·2). In taking into account of the effect of unknown mechanism of composite system, we will represent the effective suppression factor from the standard basic process given by Eq. (5·2) as $f(sin\theta)$, where the difference of phase volume effect due to the mass difference is not taking into account. In a similar way, we see that the suppression factor of the processes $u_{B_1} \to d$ and $d_{B_2} \to u$ is $f(sin\theta)$ and $f(sin^2\theta)$, respectively. The decay property of composite system with such constituents will be treated by making use of the method discussed in section 3.

In the same way, we see that the suppression factor of the typical heavy neutrino decay

$$\nu_{B_1} \to e^+ + e^- + \nu_e \tag{5·5}$$

is given by $f(sin\theta)$, except by the difference due to the mass and phase volume.

§6. Possible proton-decay mechanism mediated by sub-gauge boson $W^{(s)}$

It is interesting problem by which charge 1/3 or 4/3 is possible proton decay mediated? It is known that the X boson with charge 4/3 mediates the proton decay in GUTS such as $SU(5)$ model. In the previous papers, we have discussed that it is possible to make a correspondence between GUTs picture and composite model. [*]

It should be emphasized, however, the new type of proton decay mediated by the pre-gauge boson $W^{(s)}$ with charge 1/3 is possible in our model. That is, the elementary process mediated by $W^{(s)}$ boson exchange,

$$V + \tilde{V} \to T + \tilde{T} \tag{6·1}$$

the processes

$$(TTV) \to (TTT) \ , \ (\tilde{V}\tilde{V}\tilde{T}) \to (\tilde{V}\tilde{T}\tilde{T}) \tag{6·2}$$

which are represented as

$$u \to e^+ \ , \ d \to \bar{u} \tag{6·3}$$

are caused.

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[*] It should be noted that model to explains the proton-decay problem without difficulty. A typical decay mode is known as

$$P \to e^+ + \pi_0$$

which is caused due to the X gauge boson in GUTs. In our model, this process is realized through the same process as in GUTs,

$$u + u \to X \to e^+ + \bar{d}$$

where we have regarded the 6 rishon system as X. It should be noted that the gauge bosons are assumed to be 6-body systems of rishons in the first work on the rishon model.[2] The suppression of this process will be reduced to that of the rearrangement of rishons or, equivalently, the largeness of the X boson mass.

Thus, the process

$$(uud) \rightarrow (e^+ \bar{u}u) \tag{6.4}$$

is induced, which means the proton decay process,

$$P \rightarrow e^+ + \pi_0 \tag{6.5}$$

is mediated by $W^{(s)}$ boson. In our model the proton decay is caused without the X or Y gauge bosons appearing in GUTs. It should be emphasized that in the proton decay of this type, the Majorana property of V is essential. It is impossible in the case of Dirac type V where the anti-particle $\tilde{V}$ is essentially different from V. In this sense, we will call our mechanism as "Majorana decay of proton".

§7. Discussion

In this paper, we have investigated the properties of particles with the new heavy "Majorana partners" u_{B_1}, d_{B_1}, d_{B_2}, ν_{B_1}, ν_{B_2} and ν_{B_3}. These particles will be created through pair creation by such familiar process as high-energy PP collision. These particles are, however, fairly stable in the weak decay, and the suppression factor compared with the weak decay of ordinary particles is represented as $f(sin\theta)$ with $\theta \simeq \frac{m_F}{m_{V_B}}$, where m_F, m_{V_B} is a typical mass of the rishon, heavy rishon, respectively. The explicit form of function $f(sin\theta)$ depends on the yet to be known dynamics of sub-level, nevertheless $f(sin\theta)$ dependence of decay process will suggest the appearance of Majorana partners when new particles are discovered in TeV or more high-energy region. It should be noted that our investigation is based on the standard model with (V-A) current structure, where heavy Majorana particle V_R^c appears as "sterile" particle. In a vector-like theory[8] such as SO(10) model, right-hand current appears. In such case, new rare process of V_R^c decay is possible.

It should be emphasized that our model is based on the extension of the knowledge for existence-form of matter found in Majorana neutrinos[3),9),10)] to other fundamental particle such as the V rishon as a universal property. Their possible existence should be made clear in the near future.

Our work is based on the rishon model, which is still at a hypothetical level. However, this model is based on the simple concept of the elementarity of electric charge, and in this sense this model is natural. In fact, five types of electric charge appear in GUTs,[11]

$$Q = 0, \quad 1/3, \quad 2/3, \quad 1, \quad 4/3 \tag{7.1}$$

where the 4/3 charge is carried by X gauge boson, which is considered to be the particle responsible for proton decay.

Then, as far as the charge units are concerned, it seems that GUTs are too complicated to be the final form of the theory of elementary particles.

It should be noted that the standard formulation is not yet known in the rishon model, and, as mentioned above, it is probable that the rishon is beyond ordinary

quantum field theory.[12]   However, it seems to be meaningful to treat it in the framework of conventional field theory. The formulation on sections 2 and 3 is along this treatment and it is assumed that the gauge structure of the Standard Model appears as a result of behavior of the level of leptons and quarks.

It seems that there is another possible approach, in which, the pre-electroweak structure appears in the rishon level, and a certain kind of confinement of pre-gauge bosons realizes the well-known electroweak structure at the level of leptons and quarks. In section 4, we have step into such approach, however, only a few important pictures are clarified by making use of some symbolical representations, because the fundamental dynamics of sub-system is not yet known. Why are the sub-gauge bosons confined in W_μ, Z_μ and A_μ bosons? A possible approach to the "enhancement" of these bosons is to introduce sub-colors to such pre-gauge bosons.

We have shown that our model predict a new type of proton decay mechanism mediated by the pre-gauge boson $W^{(s)}$ with electric charge 1/3. The extreme suppression of this process will be explained by sub-color confinement. It should be emphasized that the proton decay of this type is mediated by the boson with charge 1/3, in contrast to the decay in GUTs, where the proton decay is mediated by gauge bosons X and Y. Especially, it should be noted that the charge of X boson is 4/3. If we are fully in the model with sub-structure, GUTs is itself the effective theory or phenomenological theory of composite system based on sub-system, where the fundamental electric charge is,

$$Q \;=\; 0 \;\;,\;\; 1/3 \tag{7·2}$$

Finally, is there really a sub-level below the level of leptons and quarks? In our opinion, such a sub-level surely exists, and disclosing it will make it possible to predict theoretically quantities such as the Higgs coupling constants, the magnitudes of symmetry breaking $\langle \phi \rangle$, the mass spectrum and mixing parameters of all particles, etc. We conclude this paper by emphasizing that the possible existence of Majorana partners is probable, together with that of the super-partners in SUSY.

Acknowledgments

References

1) K. Koike, Prog. Theor. Phys. **108** (2002), 1165.
2) H. Harari, Phys. Lett. B **86**,(1979), 83.
   M. Shupe, Phys.Lett. B **86**,(1979), 87.
   See also Y. Ne'emann, Phys. Lett. B **82**,(1979), 69.
   K. Koike, Prog. Theor. Phys. **88** (1992), 81.
3) S. M. Bilenky and S. T. Petcov, Rev. Mod. Phys. **59** (1987), 671.
4) S. M. Bilenky and B. Pontecorvo, Phys. Rep. **41** (1978), 225.
5) L. Wolfenstein, Phys. Rev. D **17** (1978), 2369.
   S. P. Mikheyev and A. Yu. Smirnov, Yadern. Fiz. **42** (1985), 1441.
6) For further special tratments of weak interaction, see
   K. Koike and M. Konuma et al., Prog. Theor. Phys. **46** (1971), 1150,1179; **54** (1975),206 etc.

7) B. Pontecorvo, Sov. Phys. JETP **6** (1958), 429.
    See also reference 3)
8) H. Fritzsch and P. Minkowski, Ann. Phys. 93 (1975) 193.
9) M. Gell-Mann, P. Ramond and R. Slansky, *Supergravity* ed. Van Nieuwenhizen and D. Z.
    Freedman (North Holland,1979).
    T. Yanagida, *Proc. of the Workshop on Unified Theory and Baryon Number of the Universe*, Tsukuba, Ikabari, Japan, 1979.
10) Y. Fukuda et al., Phys. Rev. Lett. **81** (1998), 1562.
11) The famous $SU(5)$ GUT has the additional noteworthy property that it has five fundamental charge units. H. Georgi and S. L. Glashow, Phys. Rev. Lett. **32** (1974), 438.
12) Z. Maki, Prog. Theor. Phys. Suppl. No. 86 (1986), 313.